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NUMERICAL METHODS & OPTIMISATION

Part I: Modelling & Error Analysis

Raihana Edros
Faculty of Engineering Technology
rzahirah@ump.edu.my

Chapter Description

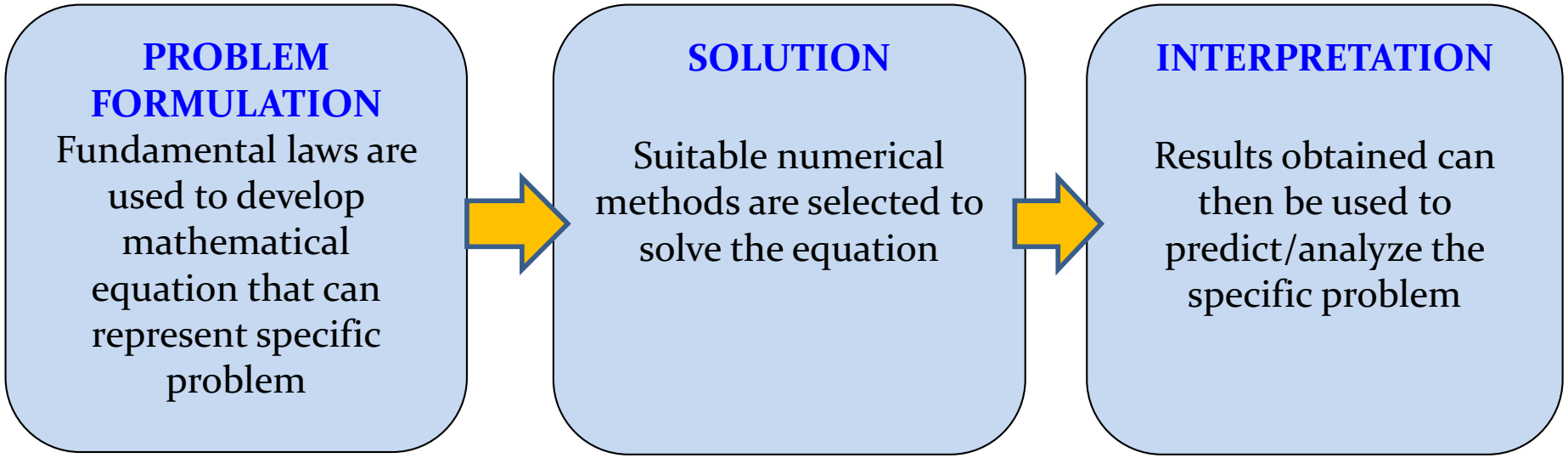
- Aims
  - Apply numerical methods in solving engineering problem and optimisation

- Expected Outcomes
  - Apply both exact and numerical solutions in mathematical modelling to solve engineering problem.
  - Calculate true percent error, percent relative error & percent tolerance
  - Estimate the truncation error by using Taylor Series

- References
  - Steven C. Chapra and Raymond P. Canale (2009), Numerical Methods for Engineers, McGraw-Hill, 6th Edition

What is numerical methods?

- Techniques used to formulate the solution of engineering problem by applying arithmetic operation.
- These methods involved large numbers and tedious arithmetic calculation



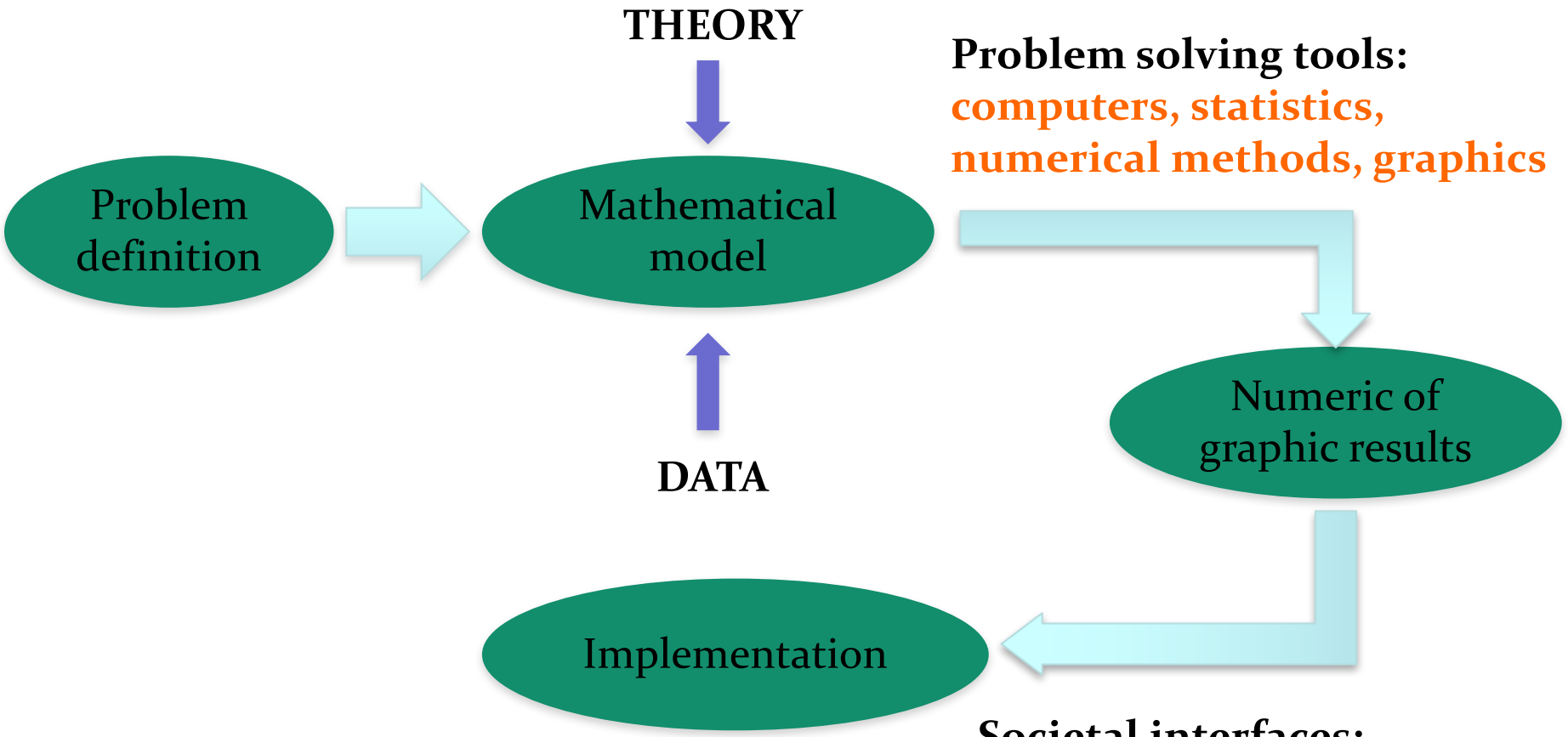
Why numerical methods?

- They are powerful problem-solving tools
  - Capable of handling large system of equations, nonlinearities, and complex geometries that mostly impossible to solve analytically
- Applied in most of industries that involve engineering
  - Commercially available prepackaged computer programs used numerical methods as basic theory underlying the methods
- Can be used with computer programming to design your own software

Mathematical Modeling & Engineering Problem Solving

- Requires understanding of engineering systems
- Through observation and experiment – empirical model
- Theoretical analysis and generalization of repeated trends – fundamental laws – solve the engineering problems
- The generalization can be modified or new ones developed as new measurements are taken – in cycle until conclusion can be drawn.

Relationship between mathematic modeling and engineering problem-solving



Modelling & Error Analysis
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Simple mathematical model

- Definition: Formulation or equation that expresses the essential features of a physical system or process in mathematical terms

- Represented as:

$$\text{Dependent variable} = f\left(\text{Independent variables}, \text{Parameters}, \text{Forcing functions}\right)$$

Simple mathematical model (cont'd)

- Dependent variable: Characteristics that reflects the behaviour or state of the system
- Independent variable: Dimensions (e.g. time & space)
- Parameters: Reflective of the systems' properties or composition
- Forcing functions: External influences acting upon the systems

Simple mathematical model (cont'd)

"In many cases, mathematical models can't be solved exactly. The only alternative is to develop a numerical solution that approximates the exact solution- "numerical methods""

Simple mathematical model: Example

- Newton Second Law:
  - The time rate of change of momentum of a body is equal to the resultant force acting on it

$$F = ma$$

  - F is net force acting on the body; m is mass of the object, and a is the acceleration
  - Rearranging results in:

$$a = \frac{F}{m}$$

Simple mathematical model: Example (cont'd)

- Characteristics of equation:
  - It describes a natural process or system in mathematical terms
  - It represents an idealization and simplification of reality
  - It yields reproducible results that can be subsequently used for predictive purposes

Conservation laws and engineering

- Conservation laws are used to predict changes with respect to time – time-variable or transient computation

$$Change = increases - decreases$$

- Also used for cases in which change is non-existent – steady-state computation. If change is equal to zero:

$$Change = 0 = increases - decreases$$

$$increases = decreases$$

Programming & Software

- Numbers of software packages are available to be used in numerical methods implementation:
  - Excel
  - MATLAB
  - FORTRAN
  - Mathematica
- Some are simple and some others are complex: the application depends largely on the range of problems to be solved
- Certain software packages is extensive – allow the user to solve a complex engineering problems
- MATLAB & Excel

Conclusion

- Both exact and numerical solutions can be used in mathematical modelling to solve engineering problems.

Main Reference

Steven C. Chapra and Raymond P. Canale (2009), Numerical Methods for Engineers, McGraw-Hill, 6th Edition

Any enquiries kindly contact:
Raihana Edros, PhD
rzahirah@ump.edu.my